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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

	)	ET Docket No. 92-9
In the Matter of	)	
	)	
Redevelopment of Spectrum to	)	RM-7981
Encourage Innovation in the	)	RM-8004
Use of New Telecommunications	)	
Technologies	)	

AMERITECH'S COMMENTS ON PROPOSED
<u>SPECTRUM TRANSITION RULES</u>

AMERITECH

By Its Attorney
Robert N. Reiland
30 South Wacker Drive
Suite 3900
Chicago, Illinois 60606
(312) 750-3385

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Summary

The Commission's proposed spectrum transition rules should be modified or clarified in order to promptly bring new wireless services to the public.

- The proposal for high power PCS licenses means an early transition of existing uses is required.
- The transition period to co-primary status should be three years, not ten years.
- Relocation services such as engineering may be provided by the emerging technology licensee in lieu of paying third parties.
- Comparable alternative facilities must meet specific capacity, useful life and reliability criteria.
- A one-year voluntary negotiation period is appropriate.
- Once relocated, no return to emerging technology spectrum should be allowed.
- The "public safety" exclusion should be reconsidered.

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AMERITECH'S COMMENTS ON PROPOSED SPECTRUM TRANSITION RULES

I. Introduction

The Commission's proposed rules governing the transition of fixed microwave licensees to new facilities provide a solid framework for the early and pervasive deployment of emerging technologies such as Personal Communications Services (PCS). Certain specific changes to these proposed rules, based in large measure on more recently obtained data and events in the industry, will promote the early and predictable availability of spectrum.[1] The Commission should promptly and clearly address outstanding transition issues to allow the early deployment of PCS and other wireless technologies and bring the benefits of these services to the public.

[1]Spectrum availability is rightly considered by the Commission to be a "major obstacle to the development of emerging technologies and the implementation of services." First Report and Order and Third Notice of Proposed Rulemaking, Docket 92-9, October 16, 1992, p. 7 (hereinafter "First Report").

II. The Commission's PCS Licensing Proposals Mean Spectrum Transition must be Shortened.

Between the last "transition" comment cycle and the due date for these Comments, a major change has occurred in the PCS equation -- the likelihood of higher power licenses. The Commission's proposal to license three or more higher power PCS providers per chosen area means increased interference between PCS licensees and existing microwave licensees will occur.[2] The need for a mechanism to more quickly (but no less fairly) relocate existing licensees to other facilities and/or spectrum is a "critical path" item.

The Commission's transition proposal also contemplates existing licensees retaining co-primary status after a transition period (unless required to move through involuntary relocation procedures).[3] However, given higher power PCS license authority, it is unlikely that a microwave licensee in an assigned band can indefinitely remain without reducing reliability and service benefits for both the microwave licensee and PCS.

Both of the foregoing influence the ultimate scope and content of final Commission action. Within the proposed transition rules, certain timing and scope provisions should be clarified or modified; these include, for example, the overall period of the transition, what constitutes "comparable alternative facilities", whether a current licensee should ever "return" to designated spectrum, and the "public safety" exclusion.

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[2]Even Ameritech's Two Tier proposal contains two high power PCS licenses. Ameritech Comments, Docket 90-314, November 9, 1992, p. 6.
[3]First Report, ¶ 24 and footnote 34.

A. The Transition Period Should be No Longer than Three Years.

A transition period to co-primary status of ten years is not consistent with the public interest in the early deployment of emerging technologies. The longer current licensees remain on designated 2GHz frequencies, the longer it will take new providers to offer wide scale, interference-free PCS. Current licensees would also be subject to potentially harmful interference during a longer transition, especially in a high power PCS environment.

Recent results from Ameritech's PCS trial indicate "frequency sharing" to be impractical for fixed uses in spectrum subject to higher power licenses.[4] Even with lower power PCS licenses, the potential for interference between microwave and PCS users remains high due to the portable nature of PCS handsets and other wireless "CPE". The Commission should act to transition spectrum to co-primary PCS uses in the shortest reasonable time -- three years -- and ensure prompt and fair involuntary relocation procedures are implemented.[5] The loss of benefit by an extended transition (merely to co-primary status) of ten years is difficult to quantify, but certain to occur.

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[4]See Attachment 1, Ameritech Analysis on Spectrum Sharing.

[5]The transition period for "unlicensed" use spectrum should mirror those for licensed uses. The transition period should commence upon the date of the Commission's Order channeling fixed microwave bands for the relocation of incumbent 2GHz fixed microwave licensees.

B. Clarification of Reimbursable Costs Will Reduce Overall Transition Expenses.

The Commission should specifically permit the emerging technology service provider to supply the items essential for relocation (for example, legal and engineering services) in lieu of compensating third parties. In these instances, the "supplier" would stand behind the adequacy of those services. Should an incumbent insist on use of third parties, the new service provider would only reimburse the incumbent for what the new provider would have paid for that element of relocation. In addition, to the extent the incumbent realizes a benefit from the new facilities in either more capacity, greater feature or service flexibility or reliability, or longer useful life, that benefit should be addressed in the overall relocation requirements imposed upon the new service provider.

C. The Commission Should Define Comparable Alternative Facilities in Terms of Capacity, Useful Life, and Reliability.

The Commission should not allow a negotiated rulemaking process to delay the key transition element definition of comparable alternative facilities. The Comments in this proceeding should form an adequate basis for a concise statement by the Commission of what constitutes a comparable alternative facility. Prime considerations of whether alternative facilities are comparable for transition purposes include:

a) Capacity,

b) Useful life, and

c) Reliability.

The new facility should be able to carry no less volume of service than the customer's actual and reasonably expected use over the existing microwave facility. The useful life of the new facility should be no less than that remaining in the 2GHz facility. The new facility should generally be no less reliable than the existing facility. In order to avoid "over engineering", a reliability cap should be established as part of the relocation cost process. The average reliability of existing users, as described in Table 1 of Attachment 1, is about 99.999%; this level of reliability implies 5 minutes per year of outage. The Commission should establish this level as the upper limit of reliability an existing licensee can expect; absent other agreement, any increase above that level would be at the discretion, and cost, of the relocated entity. The existing Commission alternatives for dispute resolution should be available in instances where disagreements persist.

D. The FCC Should Implement a One Year Voluntary Negotiating Period.

In order to speed the fullest deployment of emerging technologies to the public, the FCC should require a one-year period of voluntary negotiations (triggered in writing) before involuntary relocation may be instituted.[6] This allows an incumbent to retain its license status until at least one year after negotiations commence; voluntary negotiations may commence any time after the Commission's Order instituting transition rules is made and, in some areas, may occur after the three-year transition to co-primary status.

[6] In come cases, a third party may be negotiating to clear spectrum.

E. Once Relocation Occurs, No Return to 2GHz Should be Permitted.

In order to ensure spectrum availability for emerging technology services to the public, relocated 2GHz users should not be allowed to reclaim any prior spectrum. It is the new service provider's *obligation* to provide comparable alternative facilities consistent with Commission criteria. A possibility that a user might return to prior spectrum destroys the fundamental purpose of the transition (i.e., clearing 2GHz spectrum in order to foster emerging wireless services).

F. The "Public Safety" Exclusion Should be Reconsidered.

Given updated information on spectrum sharing (see Attachment 1) and the Commission's "high power" licensing proposal, the "public safety" exclusion from involuntary relocation should be reconsidered.[7] To allow "public safety" licensees to retain exclusive use of a frequency will limit the ability of the public and a new licensee to obtain full benefits of the spectrum allocated to emerging technologies and will inevitably degrade the existing licensee's reliability. While Ameritech recognizes it previously supported a narrowly defined exclusion, it did so assuming a more robust ability to avoid interference -- and that ability simply does not exist in the proposed licensing scheme.[8] In order to successfully implement PCS and other emerging wireless services, all incumbent 2GHz

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[7]First Report, p. 13.

[8]See Ameritech Comments, June 5, 1992, p. 7, and Attachment 1. Even in a low power scenario, Ameritech's study demonstrates that sharing will cause service degradation to current and new users.

licensees, irrespective of their identity, must be subject to a spectrum transition plan.

III. Conclusion

The Commission should promptly publish its transition rules so it may advance to the next phase of bringing new wireless services to the public.

Respectfully submitted,

Ameritech
by its Attorney

Robert N. Reiland
30 South Wacker Drive
Suite 3900
Chicago, Illinois 60606
(312) 750-3385

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Ameritech Analysis On Spectrum Sharing

Introduction

One of the objectives of Ameritech's PCS trial has been to examine the extent to which PCS can co-exist with fixed Microwave users. By successfully implementing a large scale PCS trial system at 1.9 GHz, Ameritech has shown that PCS can share spectrum with fixed microwave users at the expense of only slightly degrading microwave user's availability. However, spectrum sharing is a much simpler undertaking when the PCS system is a low power pedestrian service which can operate anywhere within a 140MHz experimental band. With PCS systems being newly defined to include high power cellular like services, the task of sharing spectrum with fixed microwave users becomes exceedingly difficult. In order to introduce new services which both complement and compete with cellular in a timely fashion, it is clear that dedicated spectrum at 1.9 GHz is needed for PCS. The FCC has proposed a transition of current fixed microwave users out of the 1.9GHz band. However, fixed microwave users argue that transitioning of their existing links to other facilities will be less reliable. Research done by Ameritech utilizing both our trial results and microwave usage data compiled by Comsearch addresses the many questions and concerns surrounding this issue.

Ameritech Test Results on Spectrum Sharing

Ameritech's PCS trial was designed to test the sharing and interference avoidance characteristics of various RF technologies. In the initial phase of the trial, an FDMA/TDD radio technology was deployed in over 100 sites and tested to determine the effects this technology has on current fixed microwave users. These tests were conducted with a "live" microwave hop operating within the same frequency band as the PCS base stations. This link is ideal for sharing tests because its interfering transmitter is located within blocks of the trial area and its interfered receiver is located 6.6 miles Southwest of the trial.

Results of this testing include findings that:

- The average signal strength at the microwave receiver from the PCS base stations in the trial closely follows a Hata large city propagation model.
- Composite signal strength measured at the interfered microwave receiver from all PCS base stations located within the beam of the receiver was -99dBm. This degraded the receiver sensitivity by 2.5dB.
- A single PCS handset located in a high rise was greater than the interference to the microwave receiver with a level of -95dBm, and degraded the receiver sensitivity by 2.5dB.
- In order to achieve an availability of 99.9999%, this microwave link requires a composite fade margin (CFM) less than 20dB. This link is currently operating with a CFM of 51dB. Even though significant levels of PCS signals were detected at the microwave receiver, the degradation to receiver sensitivity (and therefore CFM) is only 2.5dB and does not degrade the performance of this link below 99.9999%.

A comprehensive report detailing the results of this testing was submitted with Ameritech's seventh Progress Report (dated 1/8/93) and is included with this report as Appendix 1.

Availability Studies

Microwave usage data was gathered on 13 major geographic areas from Comsearch. This data included information about the microwave equipment used, transmit power, antenna type, antenna gain, path length and Standard Industrial Classification or SIC code. This information was used to calculate availability for each link using the availability and outage time formulas found in TIA bulletin 10E Revision G.[1]

$$T = (RT_O \times 10^{-CFM/10})/I$$

Where T = yearly outage time in seconds
R = fade occurrence factor
$T_O = (t/50)(8 \times 10^6)$ for yearly availability
t = Average annual temperature in degrees F
CFM = Composite Fade Margin
I = Space Diversity Improvement Factor (= 1 for non-diversity)

The fade occurrence factor, R, is calculated using the basic outage equation for atmospheric multipath fading:

$$R = c(50/W)^{1.3}(f/4)D^3 10^{-5}$$

where c = climate and humidity factor
= 0.5 for dry climate
= 1 for average conditions
= 2 for coastal and over water paths

w = terrain roughness in feet ($20 \leq w \leq 140$)
f = frequency in GHz
D = path length in miles

Availability(%) = $[(31.536 \times 10^6 - T)/31.536 \times 10^6] \times 100$ where 31.536×10^6 represents the total number of seconds in one year.

Availability was calculated for all links within a 75 mile radius of each city using area specific information for climate factor and average temperature. Since data was not available for terrain roughness, normal terrain or w = 50 was assumed for all links. In order to compute composite fade margin (CFM), receiver threshold is needed for each link. Since specific values were not available for each link, a receiver threshold value of -80dBm was used for all analog links and -78dBm for all digital links. Path loss was calculated assuming free space loss propagation.

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[1] TIA Bulletin 10E Revision G is a draft copy of the soon to be released Bulletin 10F by TIA TR14.11 committee.

SIC code information was used to classify the links into one of seven categories. While not deciding the definitions below are appropriate or justified, for purposes of this analysis only, we accepted the grouping of SIC code categories as Government, Pipeline/Petroleum/Gas, "Public Safety", Railroad, Tollway, Utility and Other.

Utilities:	Group 49 - Electric, Gas, and Sanitary Services
Pipeline, Petroleum, and Gas:	Group 13 - Oil and Gas Extraction Group 29 - Petroleum Refining Group 46 - Pipelines, except Natural Gas
Government:	Group 91 - Exec., Leg., & General Government Group 93 - Public Finance, Taxation, & Money Group 94 - Government Human Resources Group 95 - Gov't Environment and Housing Group 97 - National Security & International
"Public Safety":	Group 92 - Justice, Public Order, and Safety
Tollway:	Group 96 - Administration of Economic Prog.
Railroads:	Group 40 - Railroad Transportation

See Figure 1 for summary of microwave links per category and per geographic area. By classifying each microwave link into one of seven categories, availability averages per geographic area and per category were obtained. In addition, availability averages were calculated per type of information being transmitted; analog, digital or video. See Table 1 for availability summary.

After examining 13 major geographic areas, little variance was found in the average availability per category. In fact, the category with the best availability was found to be Tollway with availability of 99.9998585% and the worst availability was Railroad with availability of 99.9958706%. Public Safety had the second best availability at 99.99939107%. Examining availability averages for public safety links between and within geographic areas indicate wider variations. Public safety links in Washington D.C. have an average availability of 99.9985748%, where as public safety links in Atlanta have an average availability of 99.9999966%. Since all of the microwave links are currently operational, it is doubtful that Public Safety links in Atlanta actually require a higher availability than those in Washington D.C. It appears the large variance in availability is due to the fact that many links are over-engineered with resultant availability exceeding levels actually needed.

Studies commissioned by Ameritech have addressed the effect relocation of existing 1.9GHz microwave links to the 6.7GHz band has on availability. One study completed by Comsearch addresses the transition of 42 links within 35 miles of Chicago operating in the 1.9GHz band to an alternate frequency band capable of supporting equivalent channel capacity, equivalent path length, and comparable system reliability. The 6.7 GHz band was chosen as the spectrum that could accommodate the translation of all the 1.9 GHz paths in the metropolitan Chicago area. Chicago is a good benchmark for testing the feasibility of a coordinated transition process because Chicago is one of the top 10 most congested geographic areas for 1.9GHz microwave links. See Appendix

2 on the methodology used for the Chicago Migration Study completed by Comsearch.

The results of this study showed that 100% of the links could be successfully transitioned to the 6.7GHz band without significant degradation to availability. In fact, the average availability increased from 99.998987% to 99.999487% through the transition of all links to 6.7GHz. See Table 2 and Table 3. As one can see from Table 2, the availability of some links transitioned to 6.7GHz did decrease. However, most of these links still have availability well in excess of 99.999%. It is important to note that there were a couple of links whose availability decreased below 99.999%. For those links, additional engineering would be required to optimize the system such that their availability would be at least as good as it was at 1.9GHz. This could be accomplished through antenna or equipment changes, or through the addition of diversity.

Another study completed by Comsearch focused on a transition plan to 6.7GHz for the (107) 1.9GHz links within 65 miles of Houston[2]. The Houston area represents the second most congested geographic area for 1.9GHz microwave links in the U.S. The results of this study were similar in that it was found that all but 4 paths out of 107 were able to be transitioned to 6.7GHz. The fact that there were 4 paths unable to be relocated suggests that in some cases alternate transmission media or alternate frequency bands may be required to complete a comprehensive transition plan. This study also showed that an average fade margin of 54.4dB is obtained for the new 6.7GHz links. This fade margin provides an excellent average availability of 99.9999813%.

The above two transition studies show that it is very feasible for 1.9GHz microwave links to be moved to the 6.7GHz band (and also to other bands) without sacrificing availability. In fact, there is a greater risk of degrading availability for microwave links that remain in the 1.9GHz band. As PCS users' share spectrum, the effect on the operation of 1.9GHz links is a degradation to the current users availability. This degradation will occur (the extent currently unknown) and will surely increase as the number of PCS users increase. TIA committee TR14.11 is currently establishing interference guidelines for PCS coexistence with fixed microwave in the revision of Bulletin 10E but will still be virtually impossible for two services to co-exist in the same geographical location and at the same frequency without some degradation in service. For microwave users, this degradation will only be a slight reduction in availability with resultant availability still better than 99.999%. However, if microwave users are unwilling to accept some degradation, PCS cannot exist. Therefore, it is clearly in the best interest of all parties involved to relocate current 1.9GHz microwave users to other bands in a coordinated transition and as soon as possible.

What Does Sharing Mean For Private Fixed Services and PCS?

When personal communications services are introduced into the 1850 MHz to 1990 MHz band, the reliability of the existing microwave links will likely decrease. The magnitude of this decrease in reliability depends on a number of factors that include whether a high power or low power service is offered,

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[2] Comsearch, "Exploring Alternate Bands For 1.9GHz Systems" presented at Telocator T & E Committee April 14, 1992.

the spectrum sharing and avoidance technique used, the number of PCS users, and the location of the PCS transmitters. Guaranteeing a specific level of reliability would be difficult at best with a significant amount of interference coming from the handsets of widely distributed mobile users. The Commission has suggested that public safety users should be allowed to stay indefinitely with the presumption that these users operate critical links requiring a high degree of reliability. However, it is the users who remain in the shared band, not the ones who migrate to another fixed band, who would suffer the biggest decrease in reliability. *Reliability for fixed users can be more assured in an environment which has a limited number of fixed interfering sources - such as the 6.7 GHz microwave band (or others).*

If users are allowed to stay in the band for 10 years (or worse an indefinite period of time), it would certainly mean delay in the widespread offering of new or competitive services. Not surprisingly, the highest concentration of microwave links also occurs where there are the highest number of people. High power services will be exceedingly difficult to operate in this type of shared environment. Low power services could share spectrum on a limited scale, as is currently being shown in the Ameritech trial. However, as service expands and the number of users grow, the reliability of fixed microwave links must decline. *The longer the transition period, the less likely widespread innovative new personal communications services will be available particularly in major population centers.*

Non-Uniform Duplex Spacing Complicates Matters Further

Spectrum allocated to PCS licensees with an 80 MHz duplex spacing appears to sometime coincide with the current private fixed services allocation. However, that is not always the case. In fact, as the diagram in Figure 2 shows for the Chicago area, 80 MHz duplex spacing occurs in only 51% of the links, which is a typical figure for many of the major markets. While allocating spectrum in this manner is appropriate, because the duplex spacing is routinely violated in practice it would complicate the negotiation process.

Conclusion

Short term spectrum sharing is viable at low power levels, but only as a short-term solution. As a prolonged technical solution, sharing would not benefit the fixed microwave community, potential PCS operators, or the public. Spectrum sharing for periods over 3 years may degrade the performance of fixed microwave links in an unpredictable manner. "Guaranteeing" microwave system availability can only be accomplished beyond this point with significant increases in monitoring, measuring, and policing. The recommended solution is to encourage the transition of these facilities to other reliable media with no overall economic impact on fixed system operators through a coordinated transition plan.

Availability Summary by Category																	
Market	Government	#	Pipe/Petro	#	Pub. Safety	#	Railroad	#	Tollway	#	Utility	#	Other	#	Average	#
Atlanta	99.9999414	15	99.9996279	9	99.9999966	8		0			99.999839	41	99.9999703	4	99.9998574	77
Boston	99.9994242	24	99.9988739	4	99.9966525	6		0			99.9999766	9	99.9996994	4	99.9991527	47
Chicago*	99.9997641	2	99.99827	6	99.99998915	2	99.9999817	3	99.9999791	12	99.9999868	15	99.9950537	2	99.9994936	42
Dallas	99.9999968	23	99.9997398	18		0	99.9987592	8			99.99951	18	99.9996204	6	99.9996468	73
Los Angeles	99.9996277	38	99.9989692	15		0	99.9999851	1	99.9995474	4	99.9964413	57	99.9972766	16	99.997879	131
Miami	99.9955094	47		0		0		0				0	99.9998791	3	99.9957716	50
New York	99.9999722	3	99.9986707	6	99.9999917	9		0	99.9998636	14	99.9997326	28	99.99959	6	99.9996971	66
Orlando	99.9999557	37		0	99.9999948	9		0	99.9998009	13	99.9970466	8	99.9999373	5	99.9996081	72
Philadelphia	99.9998889	12	99.9995526	9	99.9999833	2		0	99.9998625	14	99.9997162	40	99.9994478	4	99.9997422	81
San Diego	99.9998799	18		0		0		0			99.9991566	13	99.9999864	1	99.9995894	32
San Francisco	99.9998499	37	99.9957924	7		0	99.981054	4			99.9978958	18	99.999842	15	99.9981354	81
Seattle	99.9992157	23		0		0	99.9977657	4			99.9975562	13		0	99.9985314	40
Washington	99.999998	11	99.9994942	5	99.9985748	2	99.9999135	3	99.9999976	3	99.9999268	36	99.9989914	8	99.9997592	68
Average	99.99907144	290	99.9989574	79	99.99939107	38	99.9958706	23	99.9998585	60	99.9988365	296	99.9990154	74	99.9989587	860

Market	Analog	#	Digital	#	Video	#
Atlanta	99.9998533	74	99.9999604	3		
Boston	99.9991019	43	99.9995992	3		
Chicago*	99.99974736	36	99.9979711	6		
Dallas	99.9997223	60	99.9992987	13		
Los Angeles	99.9988888	97	99.9947685	32	99.9986512	2
Miami	99.9998103	41	99.9773729	9		
New York	99.9997405	44	99.9996104	22		
Orlando	99.9999316	59	99.9979936	12	99.9998975	1
Philadelphia	99.9997934	36	99.9997012	45		
San Diego	99.9995699	26	99.9996737	6		
San Francisco	99.9974831	81	99.9998847	22		
Seattle	99.998657	33	99.9979456	7		
Washington	99.9997459	57	99.9998284	11		
Average	99.99929033	687	99.9975889	191	99.99906663	3

* **NOTE: Availability study only done for 35 mile radius.**

Table 1.

Chicago Link Availability Summary					
Category	1.9 Availability	1.9 Outage in Seconds/Yr	6.7 Availability	6.7 Outage in Seconds/Yr	More Reliable Link
Government 1	99.9999539	14.54	99.99997	9.46	6.7
Government 2	99.9995743	134.25	99.9996671	104.98	6.7
Pipe/Petro 1	99.9988523	361.94	99.9994001	189.18	6.7
Pipe/Petro 2	99.9990583	296.97	99.999508	155.16	6.7
Pipe/Petro 3	99.9999297	22.17	99.9999397	19.02	6.7
Pipe/Petro 4	99.9975583	770.01	99.9976511	740.75	6.7
Pipe/Petro 5	99.994363	1777.68	99.994054	1875.13	1.9
Pipe/Petro 6	99.9998583	44.69	99.999777	70.33	1.9
Public Safety 1	99.9999887	3.56	99.9999963	1.17	6.7
Public Safety 2	99.9999896	3.28	99.9999983	0.54	6.7
Railroad 1	99.9999763	7.47	99.9999951	1.55	6.7
Railroad 2	99.9999993	0.22	99.9999856	4.54	1.9
Railroad 3	99.9999694	9.65	99.9999923	2.43	6.7
Tollway 1	100	0.00	99.9999997	0.09	1.9
Tollway 2	99.9999863	4.32	99.9999911	2.81	6.7
Tollway 3	100	0.00	99.9999998	0.06	1.9
Tollway 4	99.999995	1.58	99.9999905	3.00	1.9
Tollway 5	99.9999966	1.07	99.9999779	6.97	1.9
Tollway 6	99.9999925	2.37	99.9999775	7.10	1.9
Tollway 7	99.9999995	0.16	99.9999954	1.45	1.9
Tollway 8	99.9998622	43.46	99.9999942	1.83	6.7
Tollway 9	99.9999995	0.16	99.999996	1.26	1.9
Tollway 10	99.9999999	0.03	99.9999985	0.47	1.9
Tollway 11	99.9999994	0.19	99.999997	0.95	1.9
Tollway 12	99.9999183	25.76	99.9999914	2.71	6.7
Utility 1	99.999995	1.58	99.9999942	1.83	1.9
Utility 2	99.999971	9.15	99.9999836	5.17	6.7
Utility 3	99.9999953	1.48	99.9999956	1.39	6.7
Utility 4	99.9999359	20.21	99.9999954	1.45	6.7
Utility 5	99.9999988	0.38	99.9999961	1.23	1.9
Utility 6	99.9999957	1.36	99.9999948	1.64	1.9
Utility 7	99.9999886	3.60	99.9999904	3.03	6.7
Utility 8	99.99995	15.77	99.9999071	29.30	1.9
Utility 9	99.9999999	0.03	99.9999985	0.47	1.9
Utility 10	100	0.00	99.9999995	0.16	1.9
Utility 11	99.9999976	0.76	99.9999894	3.34	1.9
Utility 12	99.9999998	0.06	99.9999987	0.41	1.9
Utility 13	99.9999751	7.85	99.9999959	1.29	6.7
Utility 14	99.9999998	0.06	99.9999989	0.35	1.9
Utility 15	99.9999999	0.03	99.9999999	0.03	6.7
Other 1	99.9904003	3027.36	99.9996561	108.45	6.7
Other 2	99.9997071	92.37	99.9998884	35.19	6.7

Table 2.

6.7 Transition

Summary of Chicago 1.9 GHz to 6.7 GHz Availability Study			
	1.9 GHz		6.7 GHz
Average Availability (%)	99.99949358	Avg. Avail. (%)	99.99974348
Average Outage (sec)	89.70	Avg. Outage (sec)	81.35
Std. Deviation (sec)	303.10	Std. Dev. (sec)	311.35
Median Outage (sec)	2.82	Med. Outage (sec)	1.83
Minimum Outage (sec)	0.00	Min. Outage (sec)	0.03
Maximum Outage (sec)	1777.68	Max. Outage (sec)	1875.13
Number of paths where 6.7 GHz is at least as reliable as 1.9 GHz = 21 out of 42			

Table 3.

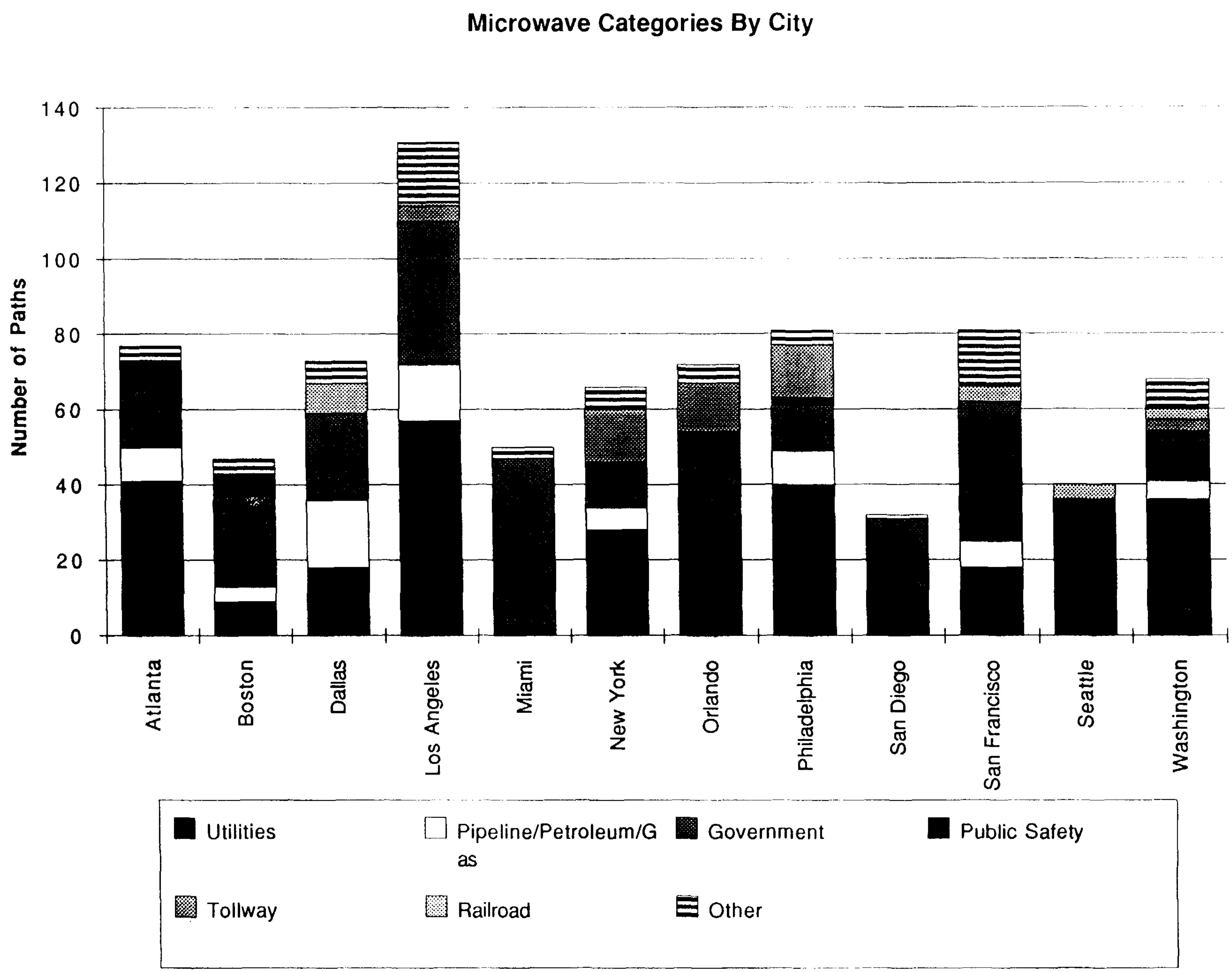
Microwave Categories By City
Number of Paths
140
120
100
80
60
40
20
0
Atlanta
Boston
Dallas
Los Angeles
Miami
New York
Orlando
Philadelphia
San Diego
San Francisco
Seattle
Washington
Utilities
Pipeline/Petroleum/Gas
Government
Public Safety
Tollway
Railroad
Other

Figure 1.

Private Microwave Duplex Frequency Spacing within 70 M of Chicago (76 Links)

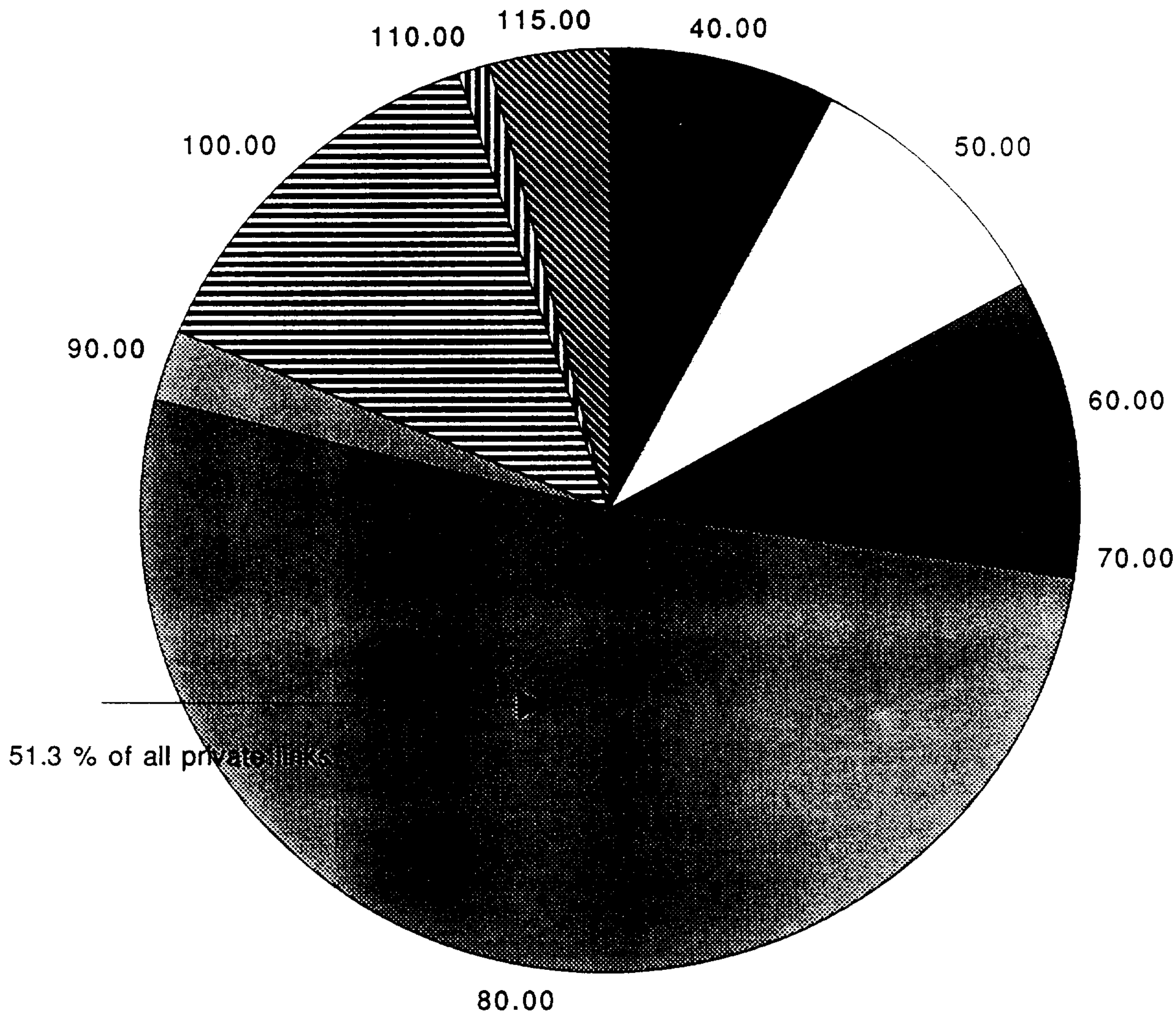

Figure 2.

Appendix 1

Ameritech Spectrum Sharing
Tests and Recommendations for Coexistence

taken from

Ameritech's Seventh Progress Report
January 7, 1993

Ameritech Spectrum Sharing

Tests and Recommendations for Coexistence

INTRODUCTION

In June of 1992, Ameritech launched a technical and market trial of PCS. Approximately 400 customers are currently involved in the trial to test various PCS features including telepoint, paging, two way service, and mobility. To provide areas of contiguous coverage, over 125 low power (20 dBm EIRP) PCS base stations have been deployed in three areas of Chicago (Downtown, Near North and a Northwest suburb) Throughout the duration of the trial, Ameritech will be testing FDMA, TDMA and CDMA radio technologies. One of Ameritech's main trial objectives is to test the sharing and interference avoidance characteristics associated with all three radio technologies with microwave.

In the initial phase of the trial, an FDMA/TDD radio technology has been utilized in the base station equipment. Forty 80 KHz wide channels spaced 200 KHz apart are being used between 1921.1 and 1928.9 MHz. This frequency band was chosen to avoid interference with any fixed microwave users operating within the trial area. However, within this band, there exists one microwave hop that is currently being used for PCS spectrum sharing studies. This microwave hop consists of a 1925 MHz transmitter located within three blocks of the Chicago Downtown trial area on top of the Gateway Building, and its corresponding receiver located 6.6 miles to the Southwest at Elsdon. See Figure 1.

The following details the results of interference tests done between the PCS system and the microwave link These tests have been constructed to obtain quantitative data on the effects the narrow band FDMA radio technology has on the analog FDM microwave link. Following the interference test results is a discussion on how these results effect common thoughts on exclusion zones and acceptable fade margins.

INTERFERENCE TEST RESULTS

Base Station Measurements: Elsdon site

At both ends of the microwave hop, the signal strength transmitted from each of the PCS base stations installed in the Chicago Downtown area for the trial were measured. The average signal strength from the 17 base stations measured at the Elsdon site (6.7 to 7.5 miles away) was found to be -113.34 dBm with a standard deviation between base stations of 3.6 dB. ***The average signal strength follows a Hata large city propagation model very closely.*** To calculate the received signal strength from the path loss Hata predicts, the following information is needed:

PCS Base Station (EIRP)	20.2 dBm (isotropic)
Microwave Antenna Gain	31.1 dBi
Microwave Receiver Cable Loss	2.0 dB
Antenna Discrimination	0.0 dB (assume PCS sites within main beam)

Using Hata large city with a distance of 7 miles, PCS base station height of 15 meters and a microwave antenna height of 24 meters results in a received signal strength of

-113.67 dBm. Even though the average of all base stations measured followed Hata, there were some exceptions. The most significant being the strongest base station with a signal strength measured at the Elsdon site of -106.9 dBm.

When all the base stations are considered simultaneously, the combined signal strength from all the detectable base stations measured at the far end of the microwave link was found to be -99 dBm. This level is not dominated by one or two extraordinary strong sites but is the summation of many sites with signal strengths near the noise floor.

Base Station Measurements: Gateway Building

Signal strengths were also measured at the downtown end of the microwave link on top of the 37 story Gateway building. This building is within three blocks of the closest PCS base station and about 1 mile from the furthest PCS base station located in downtown Chicago. None of the sites are within LOS of the microwave antenna. The combined signal strength from all the detectable base stations measured at the Gateway building is -90 dBm. This level is dominated primarily from two sites. Unlike the measurements made at the Elsdon site, the variance in signal strength measured at the Gateway building are much greater. The strongest signal strengths were found from two of the closest PCS sites and was measured at -92.5 dBm and -94.5 dBm. The weakest signal strengths observed were below -110 dBm. Correlating a propagation formula such as Hata against the measured signal strengths becomes more difficult when evaluating propagation distances less than 1 km and antenna heights above 25 km. Nevertheless, calculations shown below using both Hata urban and free space loss indicate that the ***PCS signal levels received at the microwave receiver are closer to following Hata large city than free space.***

PCS Base Station (EIRP)	20.2 dBm (isotropic)
Microwave Antenna Gain	31.1 dBi
Microwave Receiver cable loss	2.0 dB
Antenna Discrimination	-25.0 dB (PCS sites are located on back side of antenna)

Using a PCS base station height of 15 meters, a microwave antenna height of 24 meters and a distance of 1 km results in a received signal strength from a PCS base into the microwave receiver of -100.9 dBm. If Hata urban is extended to a microwave antenna height of 120 meters, the received signal strength is -91.3 dBm. If the free space loss propagation equation is used, the received signal strength becomes -73.8 dBm.

PCS Handset Measurements: Elsdon Site

The PCS handset will be a significant component in studying the interference potential PCS has on existing microwave. Unlike its base station counterpart, the handset does not remain fixed and will attempt service in a wide variety of locations. One of the most significant locations to the microwave receiver will be a location that is line of site to the microwave antenna. In most cases this will occur when the handset is located in a high rise or on a balcony. Because of the importance of this case, this scenario was tested in our PCS trial area. This was tested by keying up a handset located near the southwest corner window of the 37th floor of the Ameritech facility located in the downtown Chicago. This location is 1 and 1/2 blocks away from the Gateway microwave transmitter and approximately 6.7 miles from the microwave receiver and is near line of sight. Plot 1 shows the signal strength of the handset and home base station keyed at 1.9261 GHz as measured with a spectrum analyzer at the Elsdon site receiver. This plot shows the signal level from the handset and base to be -95 dBm.

The signal strength from this one handset was greater than any of the signal strengths measured from the PCS base stations and was even greater than the combined signal strength of all base stations. Propagation predictions using Hata are not applicable in cases where the handset is elevated. However, the signal strength measured at this receiver is over 20 dB less than the signal strength predicted from a free space loss equation. (Free space loss predicts a signal strength of -72.5 dBm)

Receiver Sensitivity Measurements

A variety of receiver sensitivity measurements were made with a Cushman selective level meter to quantify the effects operating PCS base stations have on the FDM-FM microwave radio (Motorola MR200). See figure 2 for the set up. These measurements were made at the low, middle, and high slot for a 300 channel radio. An FM signal generator was used with a carrier frequency of 1.9261 GHz and 38 KHz modulation to simulate different levels of PCS interference. The FM signal generator was coupled into the receive path of the microwave radio through a 16:1 dB coupler in which the through path experienced 1 dB attenuation and the coupled path (FM signal generator) experienced 16 dB of attenuation. Different levels of PCS interference were injected and the RF path attenuated until the noise level rose to -60 dBm (30 dB SNR). Baseband levels for this radio were set at -30 dBm. The following tables summarize the results. In addition, see plots 2 and 3 that show the baseband output with the microwave path attenuated 20 dB without and with PCS interference at -90 dBm.

Table 1. Level of PCS Interference for 1 dB Degradation in Receiver Sensitivity

Baseband Slot	Interference Level
110 KHz (Low)	-95 dBm
538 KHz (Middle)	-101 dBm
1139.7 KHz (High)	-102 dBm

Table 2. Degradation in Receiver Sensitivity With Different Levels of PCS Interference

Baseband Slot	Degradation at -90 dBm	Degradation at -99 dBm
110 KHz (Low)	2.3 dB	0 dB
538 KHz (Middle)	6.5 dB	1.2 dB
1139.7 KHz (High)	8.8 dB	2.5 dB

Table 1 indicates that a narrow band PCS system such as CT2 at 1.9 GHz can cause a 1 dB degradation in receiver sensitivity to a microwave receiver with very little signal strength. The amount of interference needed to cause this degradation decreases as the baseband slot(s) affected increases. Table 2 shows the amount of degradation in receiver sensitivity at two levels of interference. Interference at a level of -90 dBm is representative of the worst case interference received at the Gateway Building if all the base stations were keyed simultaneously and all at the same frequency. Interference at a level of -99 dBm represents the signal strength received at the Elsdon site if all the base stations in the downtown trial area were keyed simultaneously and all at the same frequency.

The single near LOS interferer illustrated in plot 1 was found to cause a 2.5 dB reduction in receiver sensitivity. The effect of this interferer to the baseband of the microwave radio can be seen in plot 4 which shows the spectrum of the baseband output when the RF power into the radio is -81.5 dBm (sensitivity).

EXCLUSION ZONES AND FADE MARGINS

The interference criteria used in assessing acceptable PCS signal levels received at microwave receivers is crucial in determining exclusion zones. Several different interference criteria are documented in TIA Bulletin 10E for spectrum sharing between fixed microwave systems. A new set of interference criteria will be necessary in Bulletin 10E for spectrum sharing between PCS and microwave. The interference criteria currently specified in Bulletin 10E include:

1. Net PCS interference power equal to 6 dB below receiver thermal noise level.
2. Carrier-to-interference ratio equal to some value (e.g.. 65 dB)

3. Interference level such that the baseband signal-to-noise ratio (SNR) in analog multiplex channel is degraded by 1 dB, or digital radio BER degraded from 10^{-6} to 10^{-5}.

Assuming a 10 MHz wide microwave receiver and a 9 dB noise figure, the thermal noise floor (KTB + NF) for this receiver would be -95 dBm. Using criteria 1 would require PCS levels not to exceed levels of -101 dBm. For the microwave hop tested above, criteria 2 requires the PCS interference not to exceed -93 dBm. (Nominal receive carrier power was measured to be -28 dBm.) Using data taken above, PCS levels as low as -102 dBm are sufficient to cause interference levels which meet criteria 3. Comparing all of these levels with the PCS interference levels measured (i.e., -90 dBm for net interference into the Gateway end, -99 dBm for net interference into the Elsdon site receiver) it is found that only criteria 2 is met and only at the interference level measured at the Elsdon site.

This would suggest that operating a PCS system within this range of a microwave hop and operating at the same frequency would cause interference to the microwave hop. ***However, receiving an interfering signal at a particular level is not in itself reason to believe the microwave hop will exhibit degradation in performance.*** In order to conclude performance degradation, an expected level of performance must be degraded below a specific level. In particular, most microwave hops are designed to meet specific reliability objectives. In order to gain a true understanding of PCS's affect on the microwave hop, the impact PCS has on meeting these reliability objectives must be studied.

Lets examine the impact PCS has on this microwave hop given a target link reliability of 99.9999% (outage probability of .0001). To calculate fade margin required for desired reliability, the following commonly known relationship for composite fade margin (CFM) will be used.

$CFM=10\log[8.203X10^5XP_O/D^3]$ where P_O=probability of outage, D is distance in miles and terrain/climatic factors are normal.

The distance between the two ends of the microwave link under study is 6.6 miles and is comprised of a single hop. Since this is a very short distance, the CFM calculates to 5.5 dB. Keeping consistent with Telocator's recommendation for short hops, a minimum fade margin protection of 10 dB will be used. In addition, another 10 dB will be added for more adverse fading environments and/or stricter outage probabilities. This results in a necessary fade margin of 20 dB. Currently this microwave hop has a 51 dB fade margin. The effect PCS has on this hop is not an issue of excessive interference that will warrant this link inoperable but a degradation to its operational fade margin. The worst case degradation found during our interference testing was experienced in a high baseband slot (1139.7 KHz) and with PCS interference at a level of -90 dBm. This degradation is an 8.8 dB reduction to the receiver sensitivity or an 8.8 dB degradation to the fade margin resulting in an operational fade margin of 42.2 dB. ***This implies that even though significant levels of PCS interference are detectable at this particular microwave hop, operation with respect to meeting reliability objectives is not impacted.***

If the acceptable interference criteria was based on exceeding reliability objectives then one might conclude that operating a PCS system within this range of this microwave hop would be acceptable. The relationship brought out by this analysis between required fade margin and operational fade margin shows the extent in which some operational microwave hops have been over designed. This over design of existing microwave hops should be taken advantage of in the design of PCS systems co-existing with fixed microwave. In particular, PCS interference levels and therefore exclusion zones should be engineered on a hop by hop basis so that current reliability objectives and fade margins are taken into account.

MICROWAVE/PCS NEGOTIATIONS

Successful deployment of a PCS system is contingent upon the ability of PCS to co-exist with microwave. Successful coexistence will rely heavily upon the ability of the PCS operator and fixed microwave user to engage into friendly negotiations with benefits resulting for both parties. Areas of negotiation include: relocation to a different frequency band, establishment of interference levels other than those established in Bulletin 10, microwave link optimization, and possibility of using a portion of the licensed bandwidth. The type of negotiation required will be dependent on the relative importance the microwave hop has on the desired PCS coverage area.

Even if relocation is unnecessary or not desired, negotiations are necessary with microwave users to better understand individual requirements of link availability and fade margins. In fact, the microwave hop may need to be tested and optimized so that confidence in the fade margin can be obtained.

Inquiries should also be made to determine if any of the microwave user's licensed spectrum is unused. This unused spectrum would be most likely associated with analog hops which are not loaded to capacity. Through negotiations, agreements could be made which allow PCS operation within select frequency bands that further increase avoidance capabilities. See Figure 3.

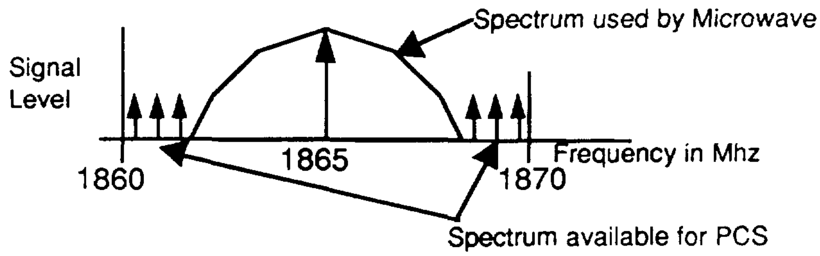

Figure 3.

CONCLUSION

Measurements made on a live microwave link with its receiver located in the main beam of a live PCS trial area have shown that the Hata Urban propagation model applies well for PCS base stations. However, it was also found that a single elevated in-building handset may result in a stronger received signal strength than the cumulative effect of many PCS base stations. Therefore, a more realistic propagation model should be used for handsets elevated and in-building. ***This should be the Hata model but with a gain factor added for handset elevation.*** By working through availability calculations, it has also been shown that realistic levels of PCS signals can exist at a microwave receiver without degrading the reliability of the microwave link to unacceptable levels. The success of PCS relies upon the ability of TR14.11 to include reasonable criteria for interference and reasonable propagation models into Bulletin 10. ***This criteria should include PCS levels based on required microwave availability and the Hata propagation model.***